

(19)



Europäisches Patentamt

European Patent Office

Office européen des brevets



(11)

EP 0 937 442 B1

(12)

EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention
of the grant of the patent:
05.01.2005 Bulletin 2005/01

(51) Int Cl.7: **A61F 2/06**

(21) Application number: **99301281.4**

(22) Date of filing: **23.02.1999**

(54) **Bifurcated axially flexible stent**

Abzweigender, in axialer Richtung flexibler Stent

Stent avec bifurcation à flexibilité axiale

(84) Designated Contracting States:
**AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU
MC NL PT SE**

(30) Priority: **24.02.1998 US 28383**

(43) Date of publication of application:
25.08.1999 Bulletin 1999/34

(73) Proprietor: **Cordis Corporation**
Miami Lakes Florida 33014 (US)

(72) Inventor: **Hojeibane, Hikmat**
Princeton, New Jersey 08540 (US)

(74) Representative: **Fisher, Adrian John**
CARPMAELS & RANSFORD
43-45 Bloomsbury Square
London WC1A 2RA (GB)

(56) References cited:
WO-A-96/29955 **WO-A-96/34580**
WO-A-97/15346 **WO-A-97/26840**
NL-C- 1 000 180

EP 0 937 442 B1

Note: Within nine months from the publication of the mention of the grant of the European patent, any person may give notice to the European Patent Office of opposition to the European patent granted. Notice of opposition shall be filed in a written reasoned statement. It shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

Description

Technical Field

[0001] The present invention relates to a stent having axial flexibility and resilience in its expanded form.

Background Art

[0002] A stent is commonly used as a tubular structure left inside the lumen of a duct to relieve an obstruction. Commonly, stents are inserted into the lumen in a non expanded form and are then expanded autonomously (or with the aid of a second device in situ). A typical method of expansion occurs through the use of a catheter mounted angioplasty balloon which is inflated within the stenosed vessel or body passageway in order to shear and disrupt the obstructions associated with the wall components of the vessel and to obtain an enlarged lumen.

[0003] In the absence of a stent, restenosis may occur as a result of elastic recoil of the stenotic lesion. Although a number of stent designs have been reported, these designs have suffered from a number of limitations. These include restrictions on the dimension of the stent such as describes a stent which has rigid ends (8mm) and a flexible median part of 7-21mm. This device is formed of multiple parts and is not continuously flexible along the longitudinal axis. Other stent designs with rigid segments and flexible segments have also been described.

[0004] Other stents are described as longitudinally flexible but consist of a plurality of cylindrical elements connected by flexible members. This design has at least one important disadvantage, for example, according to this design, protruding edges occur when the stent is flexed around a curve raising the possibility of inadvertent retention of the stent on plaque deposited on arterial walls. This may cause the stent to embolize or more out of position and further cause damage to the interior lining of healthy vessels. (See Figure 1(a) below).

[0005] Thus, stents known in the art, which may be expanded by balloon angioplasty, generally compromise axial flexibility to permit expansion and provide overall structural integrity.

[0006] In WO 96/29955, there is shown a bifurcated stent in which a first stent portion includes an opening in a lateral wall, a second stent portion communicating with the first portion through said opening.

[0007] In WO 97/15346, there is disclosed, in a discussion of the prior art, a stent system of the type set forth in the preamble to the accompanying claim 1.

Summary of the Invention

[0008] According to the invention, there is provided a stent system as set forth in the accompanying claim 1.

[0009] Further aspects of the invention are set out in

dependent claims 2 to 7.

[0010] In this fashion, the stents are capable of being placed at a bifurcation, without any welding or any special attachments. The interlocking mechanism can be incorporated into the stent design to cause the stent to interlock at the desired position during assembly of the device.

Brief Description of the Drawings

[0011] The foregoing aspects of the invention will be more readily understood by reference to the following detailed description, taken with the accompanying drawings, in which:

Figures 1(a) and 1(b) are side views of a stent having circumferentially disposed bands wherein the stent is in axially unbent and bent positions respectively, the latter showing protruding edges;

Figures 1(c) and 1(d) are side views of an axially flexible stent wherein the stent is in unbent and bent positions respectively, the latter displaying an absence of protruding edges;

Figure 2 is a side view of a portion of the stent of Figures 1(c) and 1(d) showing the longitudinal bands, spaces, and inner radial measurements of bends in the bands being measured in inches;

Figures 3(a) and 3(b) show a portion of the stent of Figure 2 with two bands between two circumferential links (a) before expansion in the undeformed state; and (b) after expansion, in the deformed state;

Figure 4 is a view along the length of a piece of cylindrical stent (ends not shown) prior to expansion showing the exterior surface of the cylinder of the stent and the characteristic banding pattern;

Figure 5 is an isometric view of a deflection plot where the stent of Figure 2 is expanded to a larger diameter of 5mm;

Figure 6 shows a two-dimensional layout of the stent of Figure 4 to form a cylinder such that edge "A" meets edge "B", and illustrating the spring-like action provided in circumferential and longitudinal directions;

Figure 7 shows a two dimensional layout of the stent. The ends are modified such that the length (L_A) is about 20% shorter than length (L_B) and the width of the band A is greater than the width of band B;

Figure 8 shows a perspective view of a stent con-

taining flexible connectors;

Figure 9 shows a stent in which the flexible connectors are attached to stent segments, in layout form. These flexible connectors are attached in an every-other-segment pattern;

Figure 10 shows a layout view where the stent segments are connected with a flexible connector in every stent segment pattern;

Figure 11 shows a schematic of a bifurcated stent as described in the present invention when loaded on a stent delivery system;

Figure 12 shows the stents placed alone;

Figure 13 shows the stents as expanded without the delivery system; and

Figure 14 shows a modification of the stent in a layout view.

Detailed Description of Specific Embodiments

[0012] Improvements afforded by embodiments of the present invention include (a) increased flexibility in two planes of the non-expanded stent while maintaining radial strength and a high percentage open area after expansion; (b) even pressure on the expanding stent that ensures the consistent and continuous contact of expanded stent against artery wall; (c) avoidance of protruding parts during bending; (d) removal of existing restrictions on maximum of stent; and reduction of any shortening effect during expansion of the stent.

[0013] In a preferred embodiment of the invention, an expandable cylindrical stent 10 is provided having a fenestrated structure for placement in a blood vessel, duct or lumen to hold the vessel, duct or lumen open, more particularly for protecting a segment of artery from restenosis after angioplasty. The stent 10 may be expanded circumferentially and maintained in an expanded configuration, that is circumferentially rigid. The stent 10 is axially flexible and when flexed at a band, the stent 10 avoids any externally protruding component parts.

[0014] Figure 1 shows what happens to a stent 10, of a similar design to a preferred embodiment herein but utilizing instead a series of circumferentially disposed bands, when caused to bend in a manner that is likely encountered within a lumen of the body. A stent 10 with a circumferential arrangement of bands (1) experiences an effect analogous to a series of railroad cars on a track. As the row of railroad cars proceeds around the bend, the corner of each car proceeding around the bend after the coupling is caused to protrude from the contour of the track. Similarly, the serpentine circumferential bands have protrusions (2) above the surface of the stent 10 as the stent 10 bends.

[0015] In contrast, the design of the embodiment shown in Figures 1(c) and 1(d) and Figure 7 in which the bands (3) are axially flexible and are arranged along the longitudinal axis, avoids such an effect when the stent 10 is bent, so the bent bands (4) do not protrude from the profile of the curve of the stent 10. Furthermore, any flaring at the ends of the stent 10 that might occur with a stent 10 having a uniform structure is substantially eliminated by introducing a modification at the ends of the stent 10. This modification comprises decreasing the spatial frequency and increasing the width of the corresponding bands in a circumferential direction (L_A and A) compared to that of the intermediate section. (L_B and B).

[0016] In an embodiment of the invention, the spatial frequency L_A may be decreased 0-50% with respect to L_B , and the width A may be increased in the range of 0-150% with respect to B . Other modifications at the ends of the stent 10 may include increasing the thickness of the wall of the stent 10 and selective electropolishing. These modifications protect the artery and any plaque from abrasion that may be caused by the stent 10 ends during insertion of the stent 10. The modification also may provide increased radio-opacity at the ends of the stent 10. Hence it may be possible to more accurately locate the stent 10 once it is in place in the body.

[0017] The embodiment as shown in Figures 2 and 6 has the unique advantage of possessing effective "springs" in both circumferential and longitudinal directions shown as items (5) and (6) respectively. These springs provide the stent 10 with the flexibility necessary both to navigate vessels in the body with reduced friction and to expand at the selected site in a manner that provides the final necessary expanded dimensions without undue force while retaining structural resilience of the expanded structure.

[0018] As shown in both Figures 2, 4 and 6, each longitudinal band undulates through approximately two cycles before there is formed a circumferential link to an adjacent band. Prior to expansion, the wave W associated with each of the bands may have approximately the same fundamental spatial frequency, and the bands are so disposed that the wave W associated with them are spatially aligned, so as to be generally in phase with one another as shown in Figure 6.

[0019] The aligned bands on the longitudinal axis are connected at a plurality of periodic locations, by a short circumferential link to an adjacent band. Consider a first common axial position such as shown by the line X-X in Figures 4 and 6. Here an adjacent pair of bands is joined by circumferential link 7. Similarly other pairs of bands are also linked at this common axial position. At a second common axial position, shown in Figure 6 by the line Y-Y, an adjacent pair of bands is joined by circumferential link 8. However, any given pair of bands that is linked at X-X is not linked at Y-Y and vice-versa. The X-X pattern of linkages repeats at the common axial po-

sition Z-Z. In general, there are thus two groups of common axial positions. In each of the axial positions of any one group are links between the same pairs of adjacent bands, and the groups alternate along the longitudinal axis of the embodiment. In this way, circumferential spring 6 and the longitudinal spring 6 are provided.

[0020] A feature of the expansion event is that the pattern of open space in the stent 10 of the embodiment of Figure 2 before expansion is different from the pattern of the stent 10 after expansion. In particular, in a preferred embodiment, the pattern of open space on the stent 10 before expansion is serpentine, whereas after expansion, the pattern approaches a diamond shape (3a, 3b). In embodiments of the invention, expansion may be achieved using pressure from an expanding balloon or by other mechanical means.

[0021] In the course of expansion, as shown in Figure 3, the wave W shaped bands tend to become straighter. When the bands become straighter, they become stiffer and thereby withstand relatively high radial forces. Figure 3 shows how radial expansion of the stent 10 causes the fenestra to open up into a diamond shape with maximum stress being expended on the apices of the diamond along the longitudinal axis. When finite element analyses including strain studies were performed on the stent 10, it was found that maximum strain was experienced on the bands and links and was below the maximum identified as necessary to maintain structural integrity.

[0022] The optimization of strain of the stent 10 is achieved by creating as large a turn radius as possible in the wave W associated with each band in the non-expanded stent 10. This is accomplished while preserving a sufficient number of bands and links to preserve the structural integrity of the stent 10 after expansion. In an embodiment of the invention, the strain may be less than 0.57 (inches/inch) for 316L stainless steel. The expansion pressure may be 1.0-7.0 atmospheres. The number of bands and the spatial frequency of the wave W on the longitudinal axis also affects the number of circumferential links. The circumferential links contribute structural integrity during application of radial force used in expansion of the stent 10 and in the maintenance of the expanded form. While not being limited to a single set of parameters, an example of a stent 10 having a longitudinal axis and providing axial flexibility of the type shown in Figure 6, may include a stent 10 having an expanded diameter of 4mm and a length of 30mm that for example may have about 8-12 rows, more particularly 10 rows and about 6-10 slots, more particularly 8 slots (a slot is shown in Figure 6 as extending between X and Z), with a wave W amplitude of about 1/4-1/10 of a slot length, more particularly 1/8 of a slot length.

[0023] The stent 10 may be fabricated from many methods. For example, the stent 10 may be fabricated from a hollow or formed stainless steel tube that may be cut out using lasers, electric discharge milling (EDM), chemical etching or other means. The stent 10 is insert-

ed into the body and placed at the desired site in an unexpanded form. In a preferred embodiment, expansion of the stent 10 is effected in a blood vessel by means of a balloon catheter, where the final diameter of the stent 10 is a function of the diameter of the balloon catheter used.

[0024] The stent 10 of the invention can be made at any desired length, most preferably at a nominal 30mm length that can be extended or diminished by increments, for example 1.9mm increments.

[0025] It will be appreciated that a stent 10 may be embodied in a shape memory material, including, for example, an appropriate alloy of nickel and titanium; or stainless steel. In this embodiment after the stent 10 has been formed, it may be compressed so as to occupy a space sufficiently small as to permit its insertion in a blood vessel or other tissue by insertion means, wherein the insertion means include a suitable catheter, or flexible rod. On emerging from the catheter, the stent 10 may be configured to expand into the desired configuration where the expansion is automatic or triggered by a change in pressure, temperature or electrical stimulation.

[0026] An embodiment of the improved stent 10 has utility not only within blood vessels as described above but also in any tubular system of the body such as the bile ducts, the urinary system, the digestive tube, and the tubes of the reproductive system in both men and women.

[0027] In yet a further embodiment, there is described a stent 10 as presently disclosed containing a multiplicity of curvilinear segments 20. These curvilinear segments 20 are connected to each other via a generally perpendicular connector 25. The generally perpendicular connector 25 lies substantially in the plane perpendicular to the longitudinal axis of the stent 10. Each of the stent 10 segments as described herein is connected to an adjacent stent 10 segment. This is done using a series of flexible connectors. Importantly, the connectors themselves can be made narrower at their midpoints. This enhances the possibility of flexure at that point. Of course, it is to be realized that alternate designs of the connector to insure flexibility are possible, and contemplated by this invention.

[0028] In essence therefore, the stent 10 as described in Figure 8 is a stent 10 of considerable flexibility when compared to more rigid rectilinear stents. Nonetheless, the stent 10 does not depart from the basic concepts set forth herein, in that it discloses a continuously curvilinear strut. This curvilinear strut is connected to other curvilinear struts via a series of "second" more flexible connectors, described above.

[0029] In any regard, it can be seen that the stent 10 incorporates various useful members. One of them is the flexible connector in conjunction with a generally curvilinear stent. Another is the use of the generally larger struts at the ends of the stent 10 in order to provide for continued support at the stent 10 ends. A final aspect

is the use of flexible connectors amongst stent 10 segments to provide for greater flexibility.

[0030] A stent as described in the foregoing passages is known from WO 97/26840.

[0031] As can be seen from Figures 11 through 14, an improved device 100 of the present invention can be made to perform in a bifurcated fashion. In this way, the stent 101 contains a central opening 102. This central opening 102 allows for the passage of an unexpanded stent 103 of the same size. Typically of course, the two stents 101, 103 will have the same general configuration, and one can pass through the other on the same type of diameter balloon. In fact, the balloon 150 as seen in the current figures 11-14 is a bifurcated balloon, but need not be. Two separate balloons are certainly capable of performing the same function. The balloons are preferably less than 2 mm (6 Fr) in their unexpanded shape in a preferred embodiment, but of course, need not be so constrained.

[0032] As seen in figures 11-14, the first stent 101 (the lower one in the figure) is loaded on one of the balloons 151. It has an opening 102 central to it. This opening faces the upper stent 103 and balloon 152, the upper stent 102 loaded on the second balloon 152. The upper stent 103, when loaded on the second balloon 152 also has an opening 104 which faces the lower stent 101. In this fashion, as the second stent 103 is strung through the first stent 101, it is placed in such a fashion so as to have a mutually facing contact with the first stent 101. Then, as the balloon and stent combination is guided through the human anatomy, the devices will go toward a bifurcation. When this happens, the device is caused to split using various guide wire techniques. Then, each of the respective balloons are inflated.

[0033] On this inflation, the entire device is expanded such as seen in Figure 13. Thus, the entire bifurcation is covered, and yet in a much easier than typical bifurcated expansions. What is unique is that there is no welding of the stents 101, 103 together, they can be common "off-the-shelf" stents modified only slightly so as to be useful for this particular need.

[0034] It should be noted that the stent of Figures 11-14 can be designed with any slot or wire configurations or of any high density materials or composites and can be balloon expandable or self-expanding or even the combination of both. The devices can be sold separately from separate catheters to be assembled during the desired procedure by the clinicians; can be used with a bifurcated balloon or two separate balloons; or incorporated with one or more radio-opaque markers to allow for better positioning in radioopacity. The bifurcated stent delivery system is placed by crimping over two balloons and then expanded at the sight of the lesion.

[0035] In all regards, however, it is to be seen that the present invention is to be determined from the attached claims.

Claims

1. A stent system containing:

a first stent (101) having an opening (102) in its lateral wall; and
a second stent (103) having an opening (104) in its lateral wall;
the second stent (103) being emplaceable through said lateral wall opening (102) of said first stent (101) so that a portion of said second stent (103) is maintained separate from said first stent (101);

characterised in that the stents (101, 103) are capable of being rotated one with respect to the other in order for the second stent (103) to have a mutually facing contact with the first stent (101), in order to maintain said stents (101, 103) in a close fitting relationship to each other in a bifurcated lumen of the body.

2. The system of claim 1 wherein the first stent (101) has first and second ends with an intermediate section therebetween, the first stent (101) further having a longitudinal axis and a plurality of longitudinally disposed cells, wherein each cell has an opening therein; and

the second stent (103) has first and second ends with an intermediate section therebetween, the second stent (103) further having a longitudinal axis and a plurality of longitudinally disposed cells, wherein each cell has an opening therein; and each of said stents (101, 103) is capable of expanding from a first respective diameter to a larger second respective diameter; and wherein second stent (103) is configured in its first respective diameter passing through a cell of the first stent (101) in its first diameter.

3. A system according to claim 2, wherein said lateral wall openings (102, 104) are larger than the other cell openings.

4. A system according to claim 1, 2 or 3, wherein each said stent (101, 103) is formed by a series of longitudinally extending struts connected by links (7, 8) and wherein each link is axially displaced from any circumferentially adjacent link.

5. A system according to claim 4, wherein, at each one of a first group of common axial positions (X, Y, Z), there is a circumferential link (7,8) between each of a first set of adjacent pairs of struts.

6. A system according to claim 5, wherein, at each one of a second group of common axial positions (X, Y, Z), there is a circumferential link (7,8) between each

of a second set of adjacent rows of struts, wherein, along the longitudinal axis, a common axial position occurs alternately in the first group and in the second group, and the first and second sets are selected so that a given strut is linked to a neighbouring strut at only one of the first and second groups of common axial positions.

7. A system according to claim 4, 5 or 6, wherein the spatial frequency (L_A) of the wave (W) associated with each of the struts is decreased in a first end region lying proximate to the first end and in a second end region lying proximate to the second end, in comparison to the spatial frequency (L_B) of the wave in the intermediate section.

Patentansprüche

1. Stentsystem umfassend:

einen ersten Stent (101) mit einer Öffnung (102) in seiner Seitenwand; und

einen zweiten Stent (103) mit einer Öffnung (104) in seiner Seitenwand;

wobei der zweite Stent (103) durch die Seitenwandöffnung (102) des ersten Stents (101) in Stellung gebracht werden kann, so dass ein Abschnitt des zweiten Stents (103) von dem ersten Stent (101) getrennt gehalten wird;

dadurch gekennzeichnet, dass die Stents (101, 103) in der Lage sind, dass einer bezüglich des anderen gedreht werden kann, so dass der zweite Stent (103) und der erste Stent (101) wechselseitig einander gegenüberliegend in Kontakt sind, um die Stents (101, 103) in einer engen Befestigungsbeziehung zueinander in einem gegabelten Hohlraum des Körpers zu halten.

2. System nach Anspruch 1, wobei der erste Stent (101) ein erstes und ein zweites Ende mit einem dazwischenliegenden Zwischenabschnitt aufweist, der erste Stent (101) weiter eine Längsachse und eine Vielzahl von in Längsrichtung angeordneten Zellen aufweist, wobei eine jede Zelle eine Öffnung darin aufweist; und
der zweite Stent (103) ein erstes und ein zweites Ende aufweist mit einem dazwischenliegenden Zwischenabschnitt, wobei der zweite Stent (103) weiter eine Längsachse und eine Vielzahl von in Längsrichtung angeordneten Zellen aufweist, wobei eine jede Zelle eine Öffnung darin aufweist; und
wobei ein jeder der Stents (101, 103) in der Lage ist, von einem ersten entsprechenden Durchmesser auf einen größeren zweiten entsprechenden Durchmesser zu expandieren; und

wobei der zweite Stent (103) hinsichtlich seines ersten entsprechenden Durchmessers so konfiguriert ist, dass er durch eine Zelle des ersten Stents (101) in seinem ersten Durchmesser passt.

3. System nach Anspruch 2, wobei die Seitenwandöffnungen (102, 104) größer sind als die anderen Zelloffnungen.
4. System nach Anspruch 1, 2 oder 3, wobei ein jeder Stent (101, 103) durch eine Reihe von sich in Längsrichtung erstreckenden Streben ausgebildet ist, die durch Verbindungen (7, 8) verbunden sind und wobei eine jede Verbindung axial von irgendeiner in Umfangsrichtung benachbarten Verbindung versetzt ist.
5. System nach Anspruch 4, wobei an einer jeden von einer ersten Gruppe von gemeinsamen Axialpositionen (X, Y, Z) eine Umfangsverbindung (7, 8) zwischen einem jeden von einem ersten Satz von benachbarten Paaren von Streben vorhanden ist.
6. System nach Anspruch 5, wobei an einer jeden von einer zweiten Gruppe von gemeinsamen Axialpositionen (X, Y, Z) eine Umfangsverbindung (7, 8) zwischen einer jeden eines zweiten Satzes von benachbarten Reihen von Streben existiert, wobei, entlang der Längsachse, eine gemeinsame Axialposition alternierend in der ersten Gruppe und in der zweiten Gruppe auftritt und wobei die ersten und zweiten Sätze so ausgewählt sind, dass eine gegebene Strebe mit einer benachbarten Strebe an nur einer der von der ersten und der zweiten Gruppe von gemeinsamen Axialpositionen verbunden ist.
7. System nach Anspruch 4, 5 oder 6, wobei die Raumfrequenz (L_A) der Welle (W), die mit einer jeden der Streben verbunden ist, in einer ersten Endregion, die proximal zu dem ersten Ende liegt, und in einer zweiten Endregion verringert ist, die proximal zu dem zweiten Ende liegt, verglichen mit der Raumfrequenz (L_B) der Welle in dem Zwischenabschnitt.

Revendications

1. Système d'endoprothèse (ou stent) comprenant :
- une première endoprothèse (101) comprenant une ouverture (102) dans sa paroi latérale ;
 - une deuxième endoprothèse (103) comprenant une ouverture (104) dans sa paroi latérale ;

la deuxième endoprothèse (103) pouvant être insé-

rée à travers ladite ouverture de paroi latérale (102) de ladite première endoprothèse (101) de sorte qu'une partie de la deuxième endoprothèse (103) est maintenue séparée de ladite première endoprothèse (101) ;

caractérisé en ce que les endoprothèses (101, 103) sont capables d'être mises en rotation l'une par rapport à l'autre pour que la deuxième endoprothèse (103) présente un contact mutuellement opposé avec la première endoprothèse (101), afin de maintenir lesdites endoprothèses (101, 103) en relation d'ajustement précis l'une par rapport à l'autre dans un lumen bifurqué du corps.

2. Système selon la revendication 1, dans lequel la première endoprothèse (101) comprend des première et deuxième extrémités avec une section intermédiaire entre les deux, la première endoprothèse (101) comprenant en outre un axe longitudinal et une pluralité de cellules disposées longitudinalement, dans lequel chaque cellule comprend une ouverture à l'intérieur ; et

la deuxième endoprothèse (103) comprend des première et des deuxième extrémités avec une section intermédiaire entre les deux, la deuxième endoprothèse (103) comprenant en outre un axe longitudinal et une pluralité de cellules disposées longitudinalement, dans lequel chaque cellule comprend une ouverture à l'intérieur ; et

chacune desdites endoprothèses (101, 103) est capable de se dilater depuis un premier diamètre respectif jusqu'à un deuxième diamètre respectif plus grand ; et

dans lequel la deuxième endoprothèse (103) est configurée dans son premier diamètre respectif passant à travers une cellule de la première endoprothèse (101) dans son premier diamètre.

3. Système selon la revendication 2, dans lequel lesdites ouvertures de paroi latérale (102, 104) sont plus grandes que les autres ouvertures de cellule.

4. Système selon la revendication 1, 2 ou 3, dans lequel chaque dite endoprothèse (101, 103) est formée par une série de plaquettes s'étendant longitudinalement raccordées par des liaisons (7, 8) et dans lequel chaque liaison est déplacée dans le sens axial depuis une quelconque liaison adjacente dans le sens circonférentiel.

5. Système selon la revendication 4, dans lequel au niveau de chacune d'un premier groupe de positions axiales communes (X, Y, Z), il existe une liaison circonférentielle (7, 8) entre chacune d'un premier ensemble de paires adjacentes de plaquettes.

6. Système selon la revendication 5, dans lequel, au

niveau de chacune d'un deuxième groupe de positions axiales communes (X, Y, Z), il existe une liaison circonférentielle (7, 8) entre chacune d'un deuxième ensemble de lignes adjacentes de plaquettes, dans lequel, le long de l'axe longitudinal, une position axiale commune se produit de manière alternée dans le premier groupe et dans le deuxième groupe, et les premier et deuxième ensembles sont sélectionnés de sorte qu'une plaquette donnée est liée à une plaquette voisine au niveau d'un seul des premier et deuxième groupes de positions axiales communes.

7. Système selon la revendication 4, 5 ou 6, dans lequel la fréquence spatiale (L_A) de l'onde (W) associée à chacune des plaquettes est réduite dans une première zone d'extrémité se trouvant proche de la première extrémité et dans une deuxième zone d'extrémité se trouvant proche de la deuxième extrémité, en comparaison à la fréquence spatiale (L_B) de l'onde dans la section intermédiaire.

FIG. 1(a)

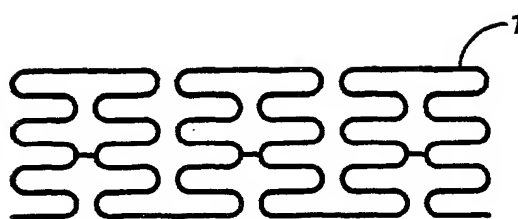


FIG. 1(b)

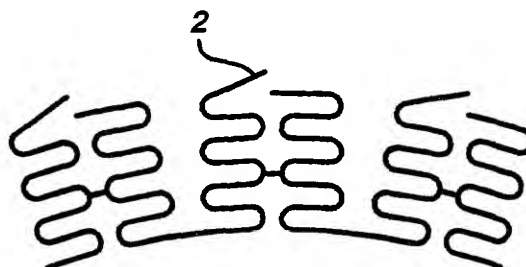


FIG. 1(c)

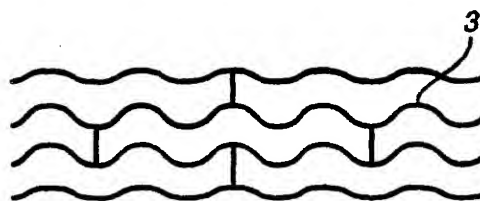


FIG. 1(d)

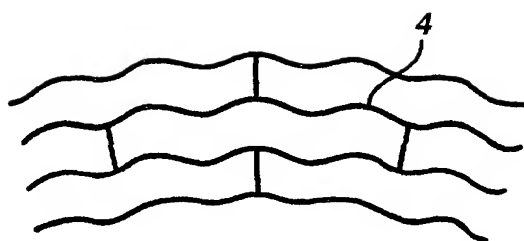


FIG. 2

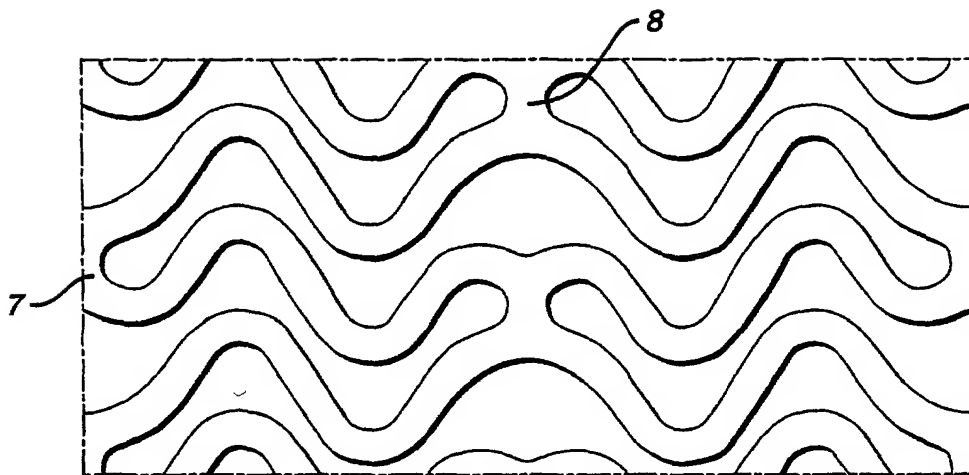


FIG. 3(a)

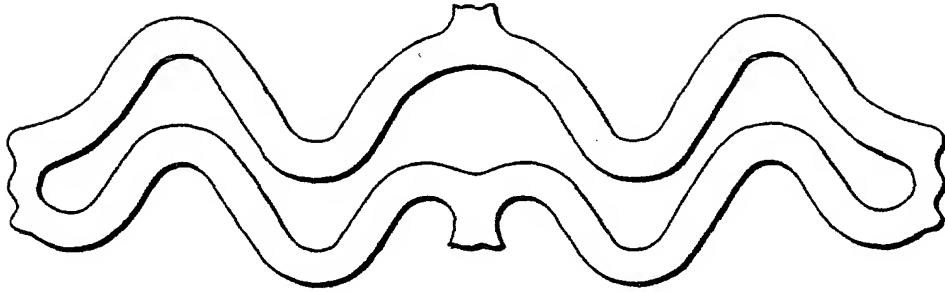


FIG. 3(b)

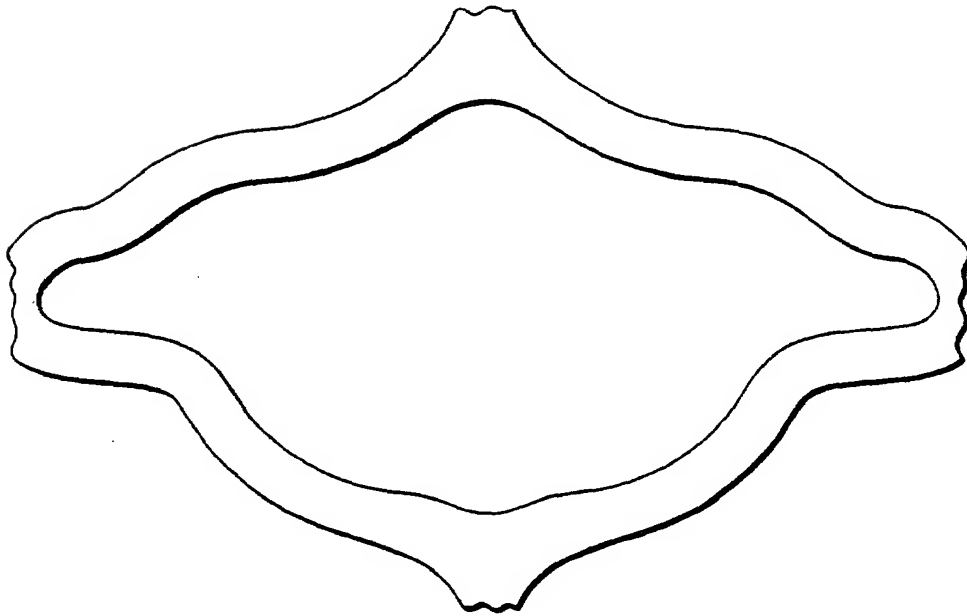


FIG. 4

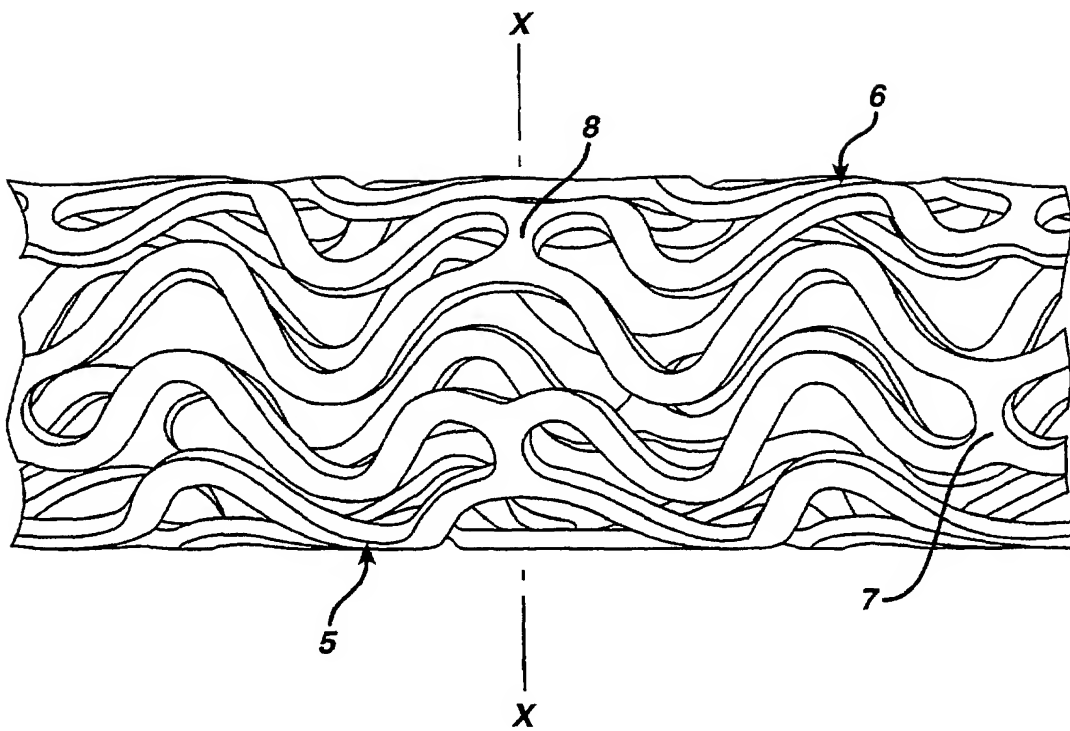


FIG. 5

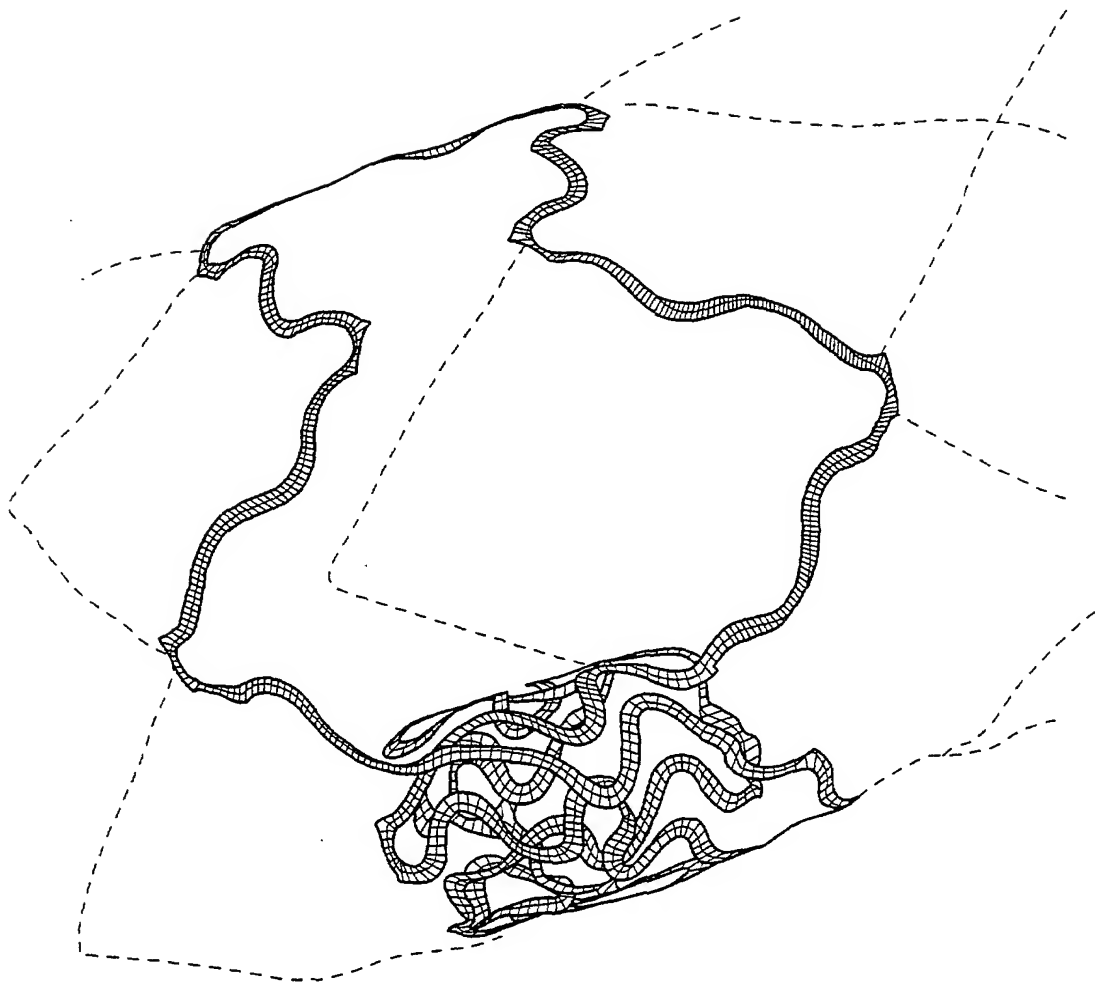


FIG. 6

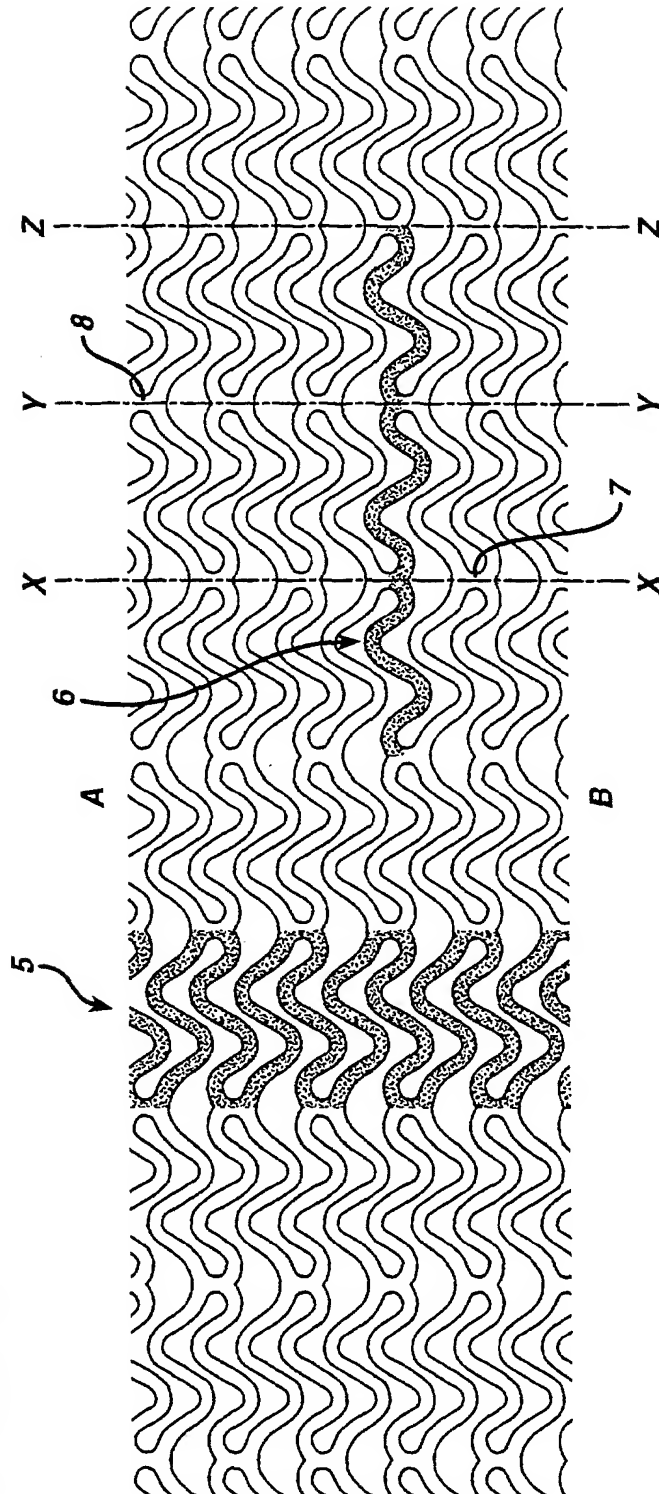


FIG. 7

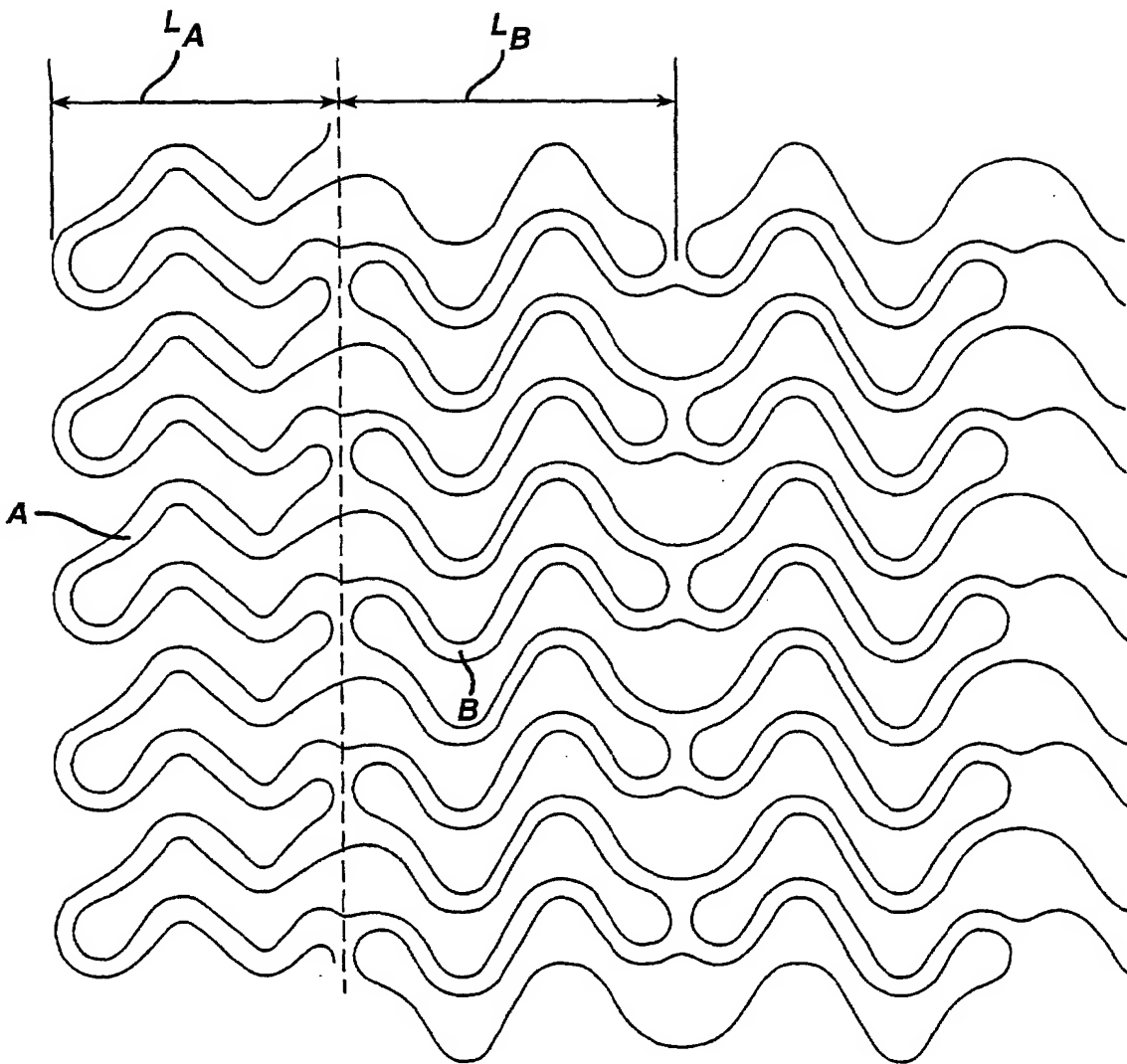


FIG. 8

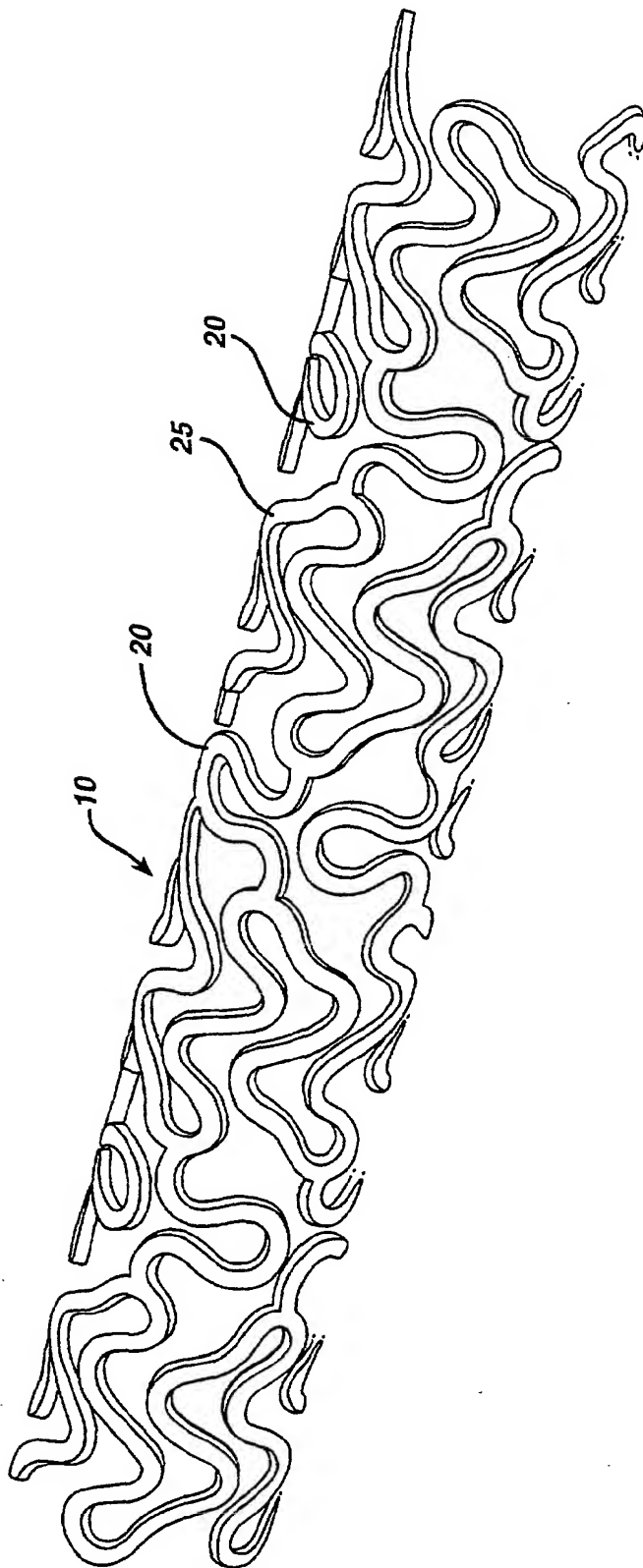


FIG. 9

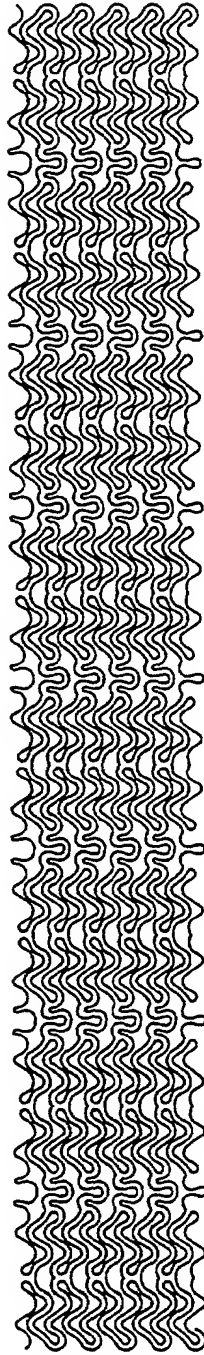


FIG. 10

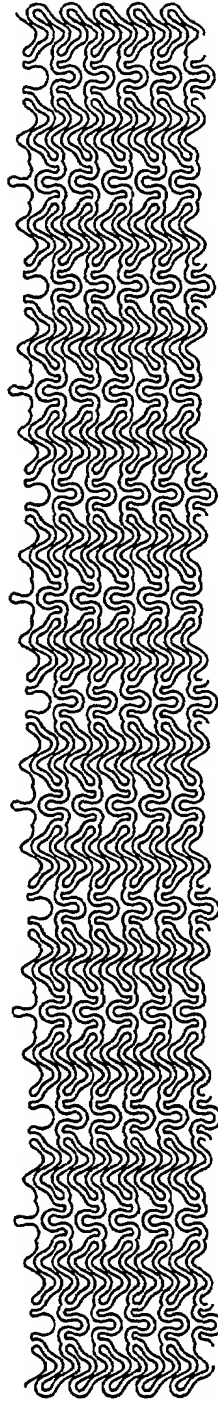


FIG. 11

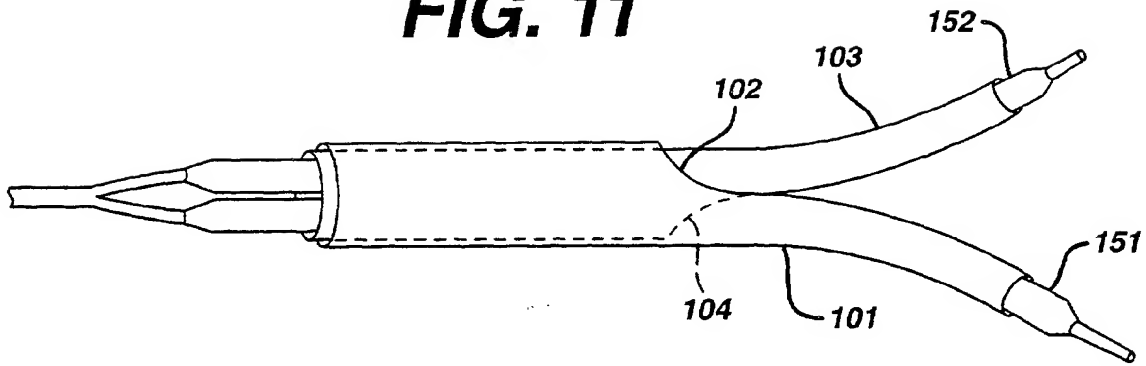


FIG. 12

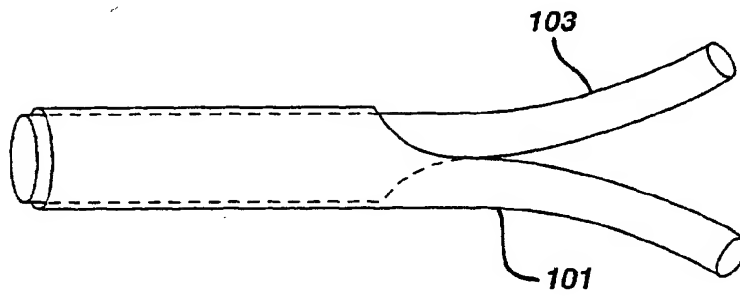


FIG. 13

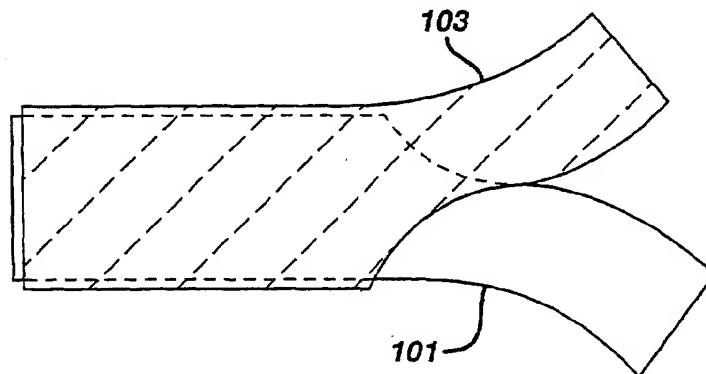


FIG. 14

